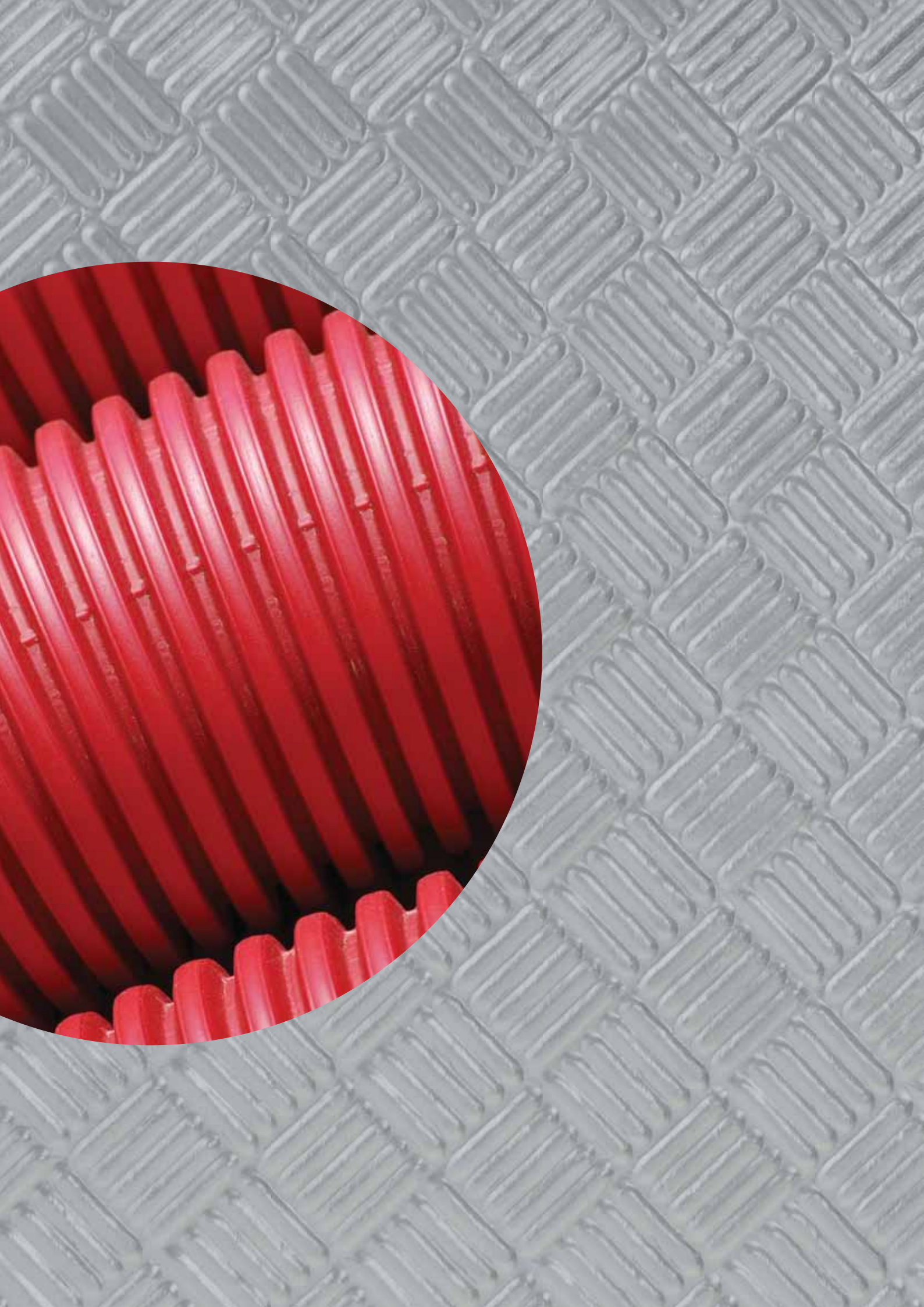




**Plastics convert iron ore to steel**  
Feedstock recycling in blast furnaces



With an annual production of about 1.3 billion tonnes worldwide, steel is the most important metallic material that can be completely recycled at the end of its life. Hot metal from the blast furnace process is the beginning of this cycle. Plastic materials rank among the second most important basic materials with an annual global production of about 260 million tonnes. Today, a modern and sustainable technology can combine plastics recovery at its end-of-life with the production of steel.



## Plastics and steel: most important materials

### New recycling technology

The ‘feedstock recycling’ of plastics waste in the metal blast furnace process provides a further option for plastics at its end-of life; in addition to the mechanical recycling and energy recovery options. In Europe three partners are forming a unique collaboration in a well integrated infrastructure: voestalpine a steel producer; AVE a leading waste management company in central Europe for household and commercial waste streams; and TBS, an SME, which cooperates with automotive and electrical OEMs for processing, treatment and recycling of shredder residues.

Synergies have been developed between the blast furnace production process with an annual potential to consume 220.000 tonnes of plastic waste and two AVE energy recovery plants with a total capacity of 600.000 tonnes per year. The upstream treatment of household and commercial waste streams by AVE produces two optimized material flows: a low energy fraction for energy recovery and a plastic-rich fraction for further treatment in an agglomeration process for the steel industry, where the material is combined with plastic

waste from household and industrial packaging waste. In this way, a specific quality of pellets is prepared and delivered for the metal blast furnace process.



### Plastics = solid oil = raw material

Since the early fifties, plastics have become increasingly important as a raw material in a wide range of applications, e.g. packaging, building and construction and automotive. Over the past 15 years, the importance of recycling plastic products at their end-of-life has begun to occupy the brains of both technicians and scientists. In addition to transforming used plastic material back into second-life products or burning it instead of coal, oil, or gas; the option of ‘feedstock recycling’ has been recognised as a new option for mixed and soiled plastic waste that is not suitable for recycling.

As one of the most demanded and finite natural resources in the world, crude oil needs to be conserved and used as efficiently as possible. A logical way forward is therefore to use plastic waste – almost 100 percent mineral oil based – in industrial applications in order to recover the material and the energy properties instead of losing its value by burying it in landfills.

### Win-win-situation for environment and economy

220.000 tonnes capacity of specified mixed plastic waste, used in a blast furnace as a reducing agent, can achieve the following savings:

- 880.000 m<sup>3</sup> of saved landfill, amounting to 11.000 trailer truck-loads.
- Over 10 millions GJ of energy saved, equal to the heating and warm water supply for e.g. 410.000 inhabitants in Germany per year.
- Over 400.000 tonnes of CO<sub>2</sub> saved per year and further reduction in emissions such as SO<sub>2</sub> and dust into the air.



Blast furnace – voestalpine, Linz/Austria.

### From iron ore to steel

Steel is derived from iron. However, this metal does not exist as a pure element in nature but only in chemical compounds, for the most part in an oxygenated form. This rock-like or earthy substance is called iron ore.

- **Iron Ore** represents – according to the mining sector – an iron content of between 30 to 70 percent of total weight. It exists in various combinations, e.g. in the relationship of 2 atoms iron (2 x Fe<sup>[1]</sup>) and 3 atoms of oxygen (3 x O<sub>2</sub><sup>[2]</sup>), Fe<sub>2</sub>O<sub>3</sub> = iron oxide.
- **Hot metal** is the liquid raw iron. It is made by removing the bonded oxygen from iron ore using

a so-called smelting reduction process. The use of plastic waste is a new option for a process that traditionally consumes coke or mineral oil.

- **Steel** is produced out of hot metal which still contains up to 4% carbon (C). This percentage needs to be reduced to a maximum of 2% down to zero, depending on the steel grade.

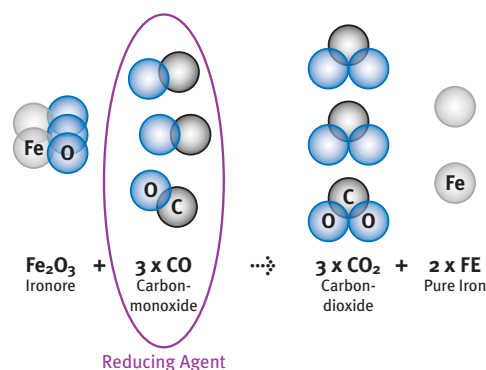
### The blast furnace process

How does the transformation from iron ore to iron work and what role can plastic play?

To remove oxygen (O) from iron ore and reduce iron ore (Fe<sub>2</sub>O<sub>3</sub>) to iron (Fe), reducing agents are required. A reducing agent is a substance which has a high affinity interaction with the oxygen in iron ore. The reducing agent is attracted to the degree that it breaks the bond between iron and oxygen, with the oxygen molecule adding itself to the reducing agent.

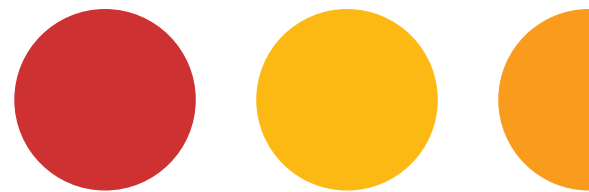
Coke or mineral oil is used as typical reducing agents. These are gasified in-situ into synthesis gas, constituting of e.g. carbon monoxide (CO), a gas which molecules consist of a single carbon- (C) and a single oxygen-atom (O) each. Carbon monoxide (CO)-gas exhibits high potential to be transformed into carbon dioxide (CO<sub>2</sub>)-gas. This is done by capturing oxygen molecules from the iron ore (Fe<sub>2</sub>O<sub>3</sub>) and thus converting it into pure, elementary iron (Fe).

When plastic waste, which can roughly be described as a hydrocarbon compound, is used as reducing agent, then synthesis gas constitutes both carbon monoxide and additional hydrogen gas. This results in an additional reducing ability compared to the traditional fossil fuel reducing agents: mineral oil or coke.



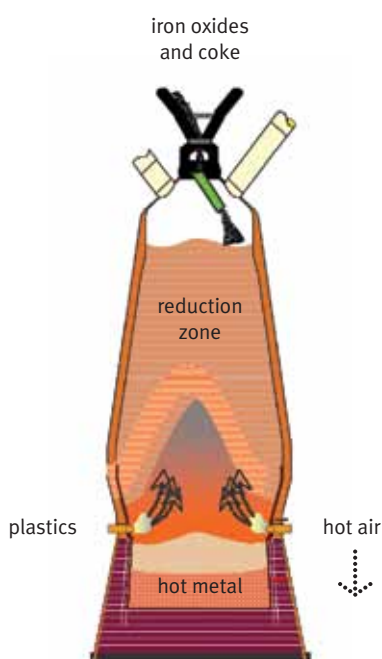
“Reduction” (simplified schematic description).

[1] Fe: Short term for “iron” derived from Latin “Ferrum”  
 [2] O: Short term for “oxygen” derived from Greek “Oxygenium”



## Technology

Iron production takes place within a blast furnace. The reactor is about 30 to 40 metres high and includes a volume of up to 4.000 m<sup>3</sup>. Iron oxides and coke are conveyed from the top.



The plastic waste is fed into the lower side of the blast furnace. The temperature in this part of the reactor reaches between 2.100°C and 2.300°C. Under these conditions the organic material gasified with the hot air into synthesis gas which contains, inter alia, carbon monoxide.

The synthesis gas reduces the iron oxides on its way down the blast furnace to hot metal by extracting oxygen. The gas has a temperature of between 900°C to 1.200°C and the iron therefore melts. The hot metal gathers at the bottom of the blast furnace and is poured out in regular intervals.

In a blast furnace, the yield is up to 10.000 tonnes of hot metal per day.

### voestalpine focuses on plastic waste

In the year 2005/06 the Austrian steel producing group voestalpine generated more than 6.2 million tonnes of steel at two locations in Austria.

Plans dating back to 2003 for the construction of one of the blast furnaces located in Linz demonstrated a capability of utilising plastic waste to produce hot metal and thus saving the steel producer around 150.000 tonnes of heavy oil per year.

Carbon monoxide as reducing agent is usually generated by gasification of coke and heavy oil or coal. Instead of using such fossil fuel materials, the new and resource-efficient procedure is to substitute traditional feedstock with end-of-life plastic waste.

### Reducing agent made of plastic waste

How are reducing agents prepared? Plastics waste is taken from separate collections of household and commercial packaging waste as well as shredder light waste from end-of-life vehicles and/or old electrical goods. These materials enter a treatment process and the material mix is specified and finally pelletized to be used as reducing agent.

The reducing agent is transported via transmission pipelines to the blast furnace and injected into the lower side directly underneath the reduction zone.



For this pneumatic conveying, the material is either shredded down into pieces only a few millimetres in diameter or pelletized by pressing through perforated plates.

### 220.000 Tonnes capacity

voestalpine is eager to utilise up to 220.000 tonnes of plastic waste per year to reduce heavy oil input.

In 2006 the first trials were performed with 30.000 tonnes of waste material in pellet form, agglomerates and granules. The successful results are the basis for further extension of the project.

The production of 1 ton of hot metal requires the use of approx. 370 kg of coke plus 90 kg of heavy oil, depending on the quality of the iron ore and the process used.

These 90 kg of heavy oil can be partly substituted with up to 70 kg of plastics waste.

Through the final scale-up, voestalpine will be able to substitute 150.000 tonnes of heavy oil with 220.000 tonnes of prepared plastic waste per year.



Via long pipe systems plastics are injected with compressed air into the blast furnace.



### Feedstock recycling

The use of plastic waste as a reducing agent for the blast furnace technology is one of the feedstock recycling options which efficiently saves primary energy resources such as mineral oil. The main benefit is not to generate heat via combustion, but to produce materials such as carbon monoxide (from synthesis gas), in order to transform iron ore into iron.

As already described, this process is based on using, *inter alia*, gaseous carbon monoxide as a reducing agent, produced during gasification of plastic waste within the blast furnace.

In this way, blast furnace technology represents an innovative approach to saving natural resources.

### Divert from landfill

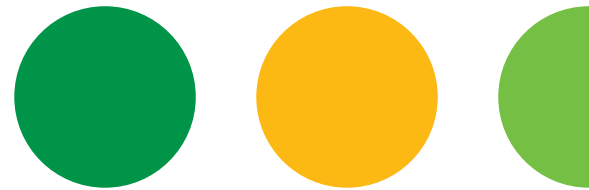
Today, plastic waste is still being deposited in landfills in many countries across Europe. This has been prohibited by law in Austria since 2004, and in Germany since 2005. Further countries followed. The European Union is considering a general ban on landfilling of high calorific waste, which should instead be recovered either as a material or in the form of energy.

### Recovery mix

There are various alternatives to the recovery of value from plastic waste. Which of these methods is most suitable?

- **Mechanical recycling** is the re-melting and transformation of plastics into new recycled products, and is often considered as the best method. However, only around 22% of post-consumer plastic waste is suitable, namely those which are available from clean and sorted waste streams, e.g. PET drinking bottles, large films or window frames.
- **Energy recovery** is currently much less valued in the public because the benefits are not yet well understood. Through energy recovery, plastic waste can be used in order to generate heat, steam or electricity. One kilogram of plastic waste has the same heating value as one litre of fuel oil. Energy recovery is suitable for mixed and soiled plastic waste which would otherwise be technically or economically difficult to recycle.
- **Feedstock recycling** processes such as the gasification of plastic waste into synthesis gas, to be used in blast furnaces as a reducing agent, is a good option in combination with the other recycling options<sup>[3]</sup>.

[3] as shown by a study of GUA / Denkstatt GmbH, Vienna 2006

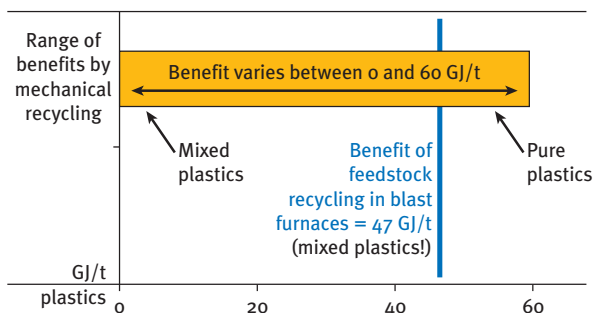


## Environmental benefit

The environmental benefit of various plastics recycling processes can be estimated by comparing the amount of energy resources saved during the alternative process options.

This calculation includes effects on greenhouse gas emissions as well. Less energy use means less environmental pollution.

### Saved energy resources



Comparison<sup>4</sup> of net savings of energy resources by mechanical and feedstock recycling processes.

The benefit of resource savings through the mechanical recycling of plastic waste is within the range of 0 to 60 GJ/t

for different mechanical processes. 60 GJ/t can only be achieved through recycling processes where homogeneous and clean plastic waste fractions are transformed into granules as a substitute for virgin material on a 1:1 ratio. For those mechanical recycling processes, where mixed plastic waste is used to produce recyclates for palisades, roof tiles, etc., the environmental benefit is comparatively small (left end of above figure). In this case the energy needed for the recycling process is equal to credit of substitution, because the materials being substituted via recycling (concrete, wood, roof tiles, etc.) do not need much energy to be produced.

In this calculation, the benefit of feedstock recycling of plastic waste in blast furnaces at approx. 47 GJ/t is undoubtedly higher than the benefits of mechanical recycling processes for mixed plastic waste.<sup>[3]</sup>

### The great demand

An optimised mix of different recovery and recycling options will ensure that the potential for plastic waste as a resource substitute is realised in the most eco-efficient, i.e. ecologically and economically efficient, way.

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